

OVERVIEW OF THE SPANISH FUEL CYCLE: TECHNICAL TOURS ORGANIZED BY SPANISH YOUNG GENERATION IN NUCLEAR (JÓVENES NUCLEARES, JJNN)

I.P. RUBIO OVIEDO, G. JIMÉNEZ VARAS, R. OCHOA VALERO

Spanish Young Generation in Nuclear (Jóvenes Nucleares, JJNN)

C/Campoamor 1º 28004 Madrid SPAIN

ABSTRACT

Spanish Young Generation in Nuclear (Jóvenes Nucleares, JJNN) is a non-profit organization that depends on the Spanish Nuclear Society (Sociedad Nuclear Española, SNE). Since one of its main goals is to spread the knowledge about nuclear power, several technical tours to facilities with an important role in the nuclear fuel cycle have been organized for the purpose of learning about the different stages of the Spanish fuel cycle.

Spanish Young Generation in Nuclear had the opportunity to visit ENUSA Fuel Assembly Factory in Juzbado (Salamanca, Spain), where it could be understood the front-end cycle which involves the uranium supply and storage, design and manufacturing of fuel bundles for European nuclear power plants. Afterwards, due to the tour of Almaraz NPP (PWR) and Santa María de Garoña NPP (BWR), it could be comprehended how to obtain energy from this fuel in two different types of reactors. Furthermore, in these two plants, the facilities related to the back-end cycle could be toured. It was possible to watch the Spent Fuel Pools, where the fuel bundles are stored under water until their activity is reduced enough to transport them to an Individual Temporary Storage Facility or to the Centralized Temporary Storage. Finally, a technical tour to ENSA Heavy Components Factory (ENSA) was accomplished, where it could be experienced at first hand how different Nuclear Steam Supply System (NSSS) components and other nuclear elements, such as racks or shipping and storage casks for spent nuclear fuel, are manufactured.

All these performed technical tours were a complete success thanks to a generous care and know-how of the workers in charge of leading the technical tours. The unanimous opinion of the participants was that taking part in this kind of activities is a worthwhile experience which has exceeded their expectations.

1. Introduction

Spanish Young Generation in Nuclear (Jóvenes Nucleares, JJNN) is a non-profit organization that depends on the Spanish Nuclear Society (Sociedad Nuclear Española, SNE). Since one of its main goals is to spread the knowledge about nuclear power, several technical tours to facilities with an important role in the nuclear fuel cycle have been organized for the purpose of learning about the different stages of the Spanish fuel cycle.

2. The Spanish Nuclear Fuel Cycle

The nuclear fuel cycle includes all processes and operations involved in manufacturing nuclear fuel, its irradiation in nuclear power reactors, as well as spent fuel reprocessing, recycling or disposing of the fission product waste produced during irradiation.

Depending on the management of the irradiated nuclear fuel, two cycle options may be considered:

- Open or once-through fuel cycle, without reuse of nuclear materials.
- Closed fuel cycle, with reuse of nuclear materials extracted from irradiated fuel.

In Spain, the closed fuel cycle was chosen for the reprocessing of irradiated nuclear fuel from the longest-serving nuclear power plants (Vandellós I NPP, José Cabrera NPP and Santa

María de Garoña NPP). This practice was interrupted in 1982, except for Vandellós I NPP. This plant was shut down in 1989, due to a turbine fire, and its fuel had to be reprocessed in its entirety. As a result of the commitments acquired from the different reprocessing contracts, several medium and high activity wastes should be returned to Spain from foreign fuel reprocessing facilities.

Nowadays the fuel cycle strategy adopted by Spain is the open or once-through cycle (see figure 1), mode of operation in which the nuclear material passes through the reactor just once. After irradiation, the fuel is stored in reactor spent fuel pools until it is sent to a storage facility, as it is done in Spanish nuclear power plants in operation (Almaraz NPP, Ascó I&II NPP, Vandellós II NPP, Cofrentes NPP and Trillo NPP).

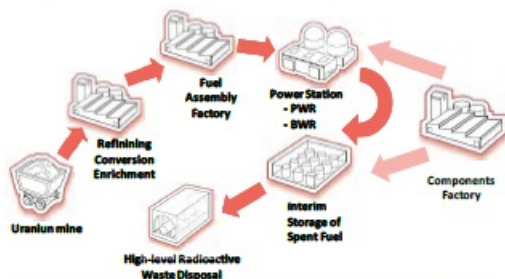


Figure 1.- Scheme of the Spanish open or once-through fuel cycle

All the activities involved in the fuel cycle may be divided into three categories:

- First category involves activities that take place prior to fuel irradiation, when fuel radioactivity levels are relatively low. These activities include milling, refining, conversion to uranium hexafluoride, enrichment in the fissile isotope ^{235}U and fuel assembly manufacturing.
- Second category of activities consists of fuel cycle design and irradiation of the fuel elements and assemblies in the reactor.
- Third category of fuel management activities includes operations on the highly radioactive spent fuel storage, shipping and disposal.

3. Spanish Fuel Cycle Facilities

Taking into account that the open or once-through cycle is the strategy adopted by Spain, it is important to make an overview about the current situation of the Spanish facilities belonging to each category of the cycle.

- First category:

All the facilities existing in Spain for the extraction of uranium ore have now ceased to operate. Certain of the mining sites have now been restored, while others are in the rehabilitation phase or are scheduled to be restored in the near future.

In addition to extraction and treatment of the ore, the first part of the cycle also involves the manufacturing of uranium concentrates. At present, the Quercus Plant, an uranium concentrates manufacturing facility, is shut down and no longer produces. Other disused concentrates manufacturing facilities, such as the Lobo G Plant, have been decommissioned or are in the final phases of dismantling and decommissioning, for example the Elefante Plant and the AUM (Andújar Uranium Mill).

The final stage of the first category of the cycle is the manufacturing of the fuel assemblies. In Spain, there is a fuel cycle facility in operation for the manufacturing of pellets, rods and fuel assemblies, located in Juzbado (Salamanca).

- Second category:

The second category of activities of the fuel cycle is the irradiation of the fuel in the reactor. Spain has eight nuclear power reactors in operation located at six sites, two power reactors closed down, in different steps of the decommissioning process, and a power reactor temporarily shut down.

- Third category:

After passing through the reactors, the irradiated fuel contains high levels of activity due to fission products and small amounts of plutonium. The last part of the cycle encompasses the management of the waste generated throughout the process. This waste may have low and intermediate or high levels of activity. The low and intermediate level waste is taken to the El Cabril disposal facility, called 'El Cabril' and located in the South of Spain. The irradiated fuel assemblies are stored in each nuclear power plant pool. However, due to the lack of capacity in reactor pools or to decommissioning, three temporary individual storage facilities have been built in three nuclear power plants sites, where the irradiated fuel assemblies are stored in dry casks. Nowadays, a centralized temporary storage facility is projected. The planned facility is designed to receive and store for decades all the spent fuel resulting from Spanish nuclear power reactors, the high-level vitrified waste and long-lived intermediate level waste generated abroad in the reprocessing of Spanish fuel and the intermediate level radioactive waste from nuclear power plants decommissioning, those with activity levels higher than 'El Cabril' low and intermediate level waste disposal facility acceptance criteria.

Besides, in figure 1, in light-red colour, it is represented an additional facility located in Spain, with an important role in the fuel cycle, which supports the second and final categories of the nuclear fuel cycle. It is the heavy components factory, which supplies Nuclear Steam Supply System (NSSS) components and other nuclear elements such as racks and shipping and storage cask for spent nuclear fuel.

4. Technical Tours

Several technical tours have been organized to comprehend the different stages of the Spanish open fuel cycle. These tours have provided an excellent opportunity for young professionals to increase their understanding of the technical process accomplished at the different Spanish fuel cycle facilities.

Spanish Young Generation in Nuclear had visited three fuel cycle facilities and the heavy components factory, which supports the second and final categories of the cycle. All of them are listed below and are located in the map of Spain shown in figure 2:



Figure 2.- Location of the nuclear facilities toured

- ENUSA Fuel Assembly Factory in Juzbado (Salamanca).
- Almaraz Nuclear Power Plant (PWR) in Almaraz (Cáceres).
- Santa María de Garoña Nuclear Power Plant (BWR) in Santa María de Garoña (Burgos).
- ENSA Heavy Components Factory in Maliaño (Santander).

The tours have allowed the participants to experience at first hand how the different activities of the fuel cycle are performed and to broaden their knowledge about the front-end cycle. As it is shown in figure 3, a wide part of the different categories of the cycle have been covered: fuel assembly factory, power stations (BWR&PWR), spent nuclear fuel pools and heavy components factory.

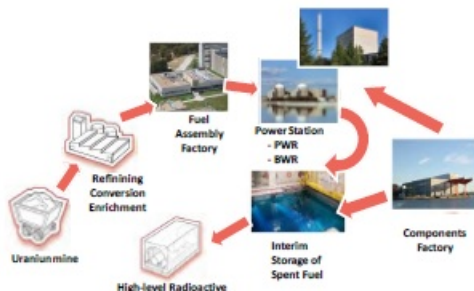


Figure 3.- Nuclear fuel cycle facilities toured

4.1. ENUSA Fuel Assembly Factory

Enusa Industrias Avanzadas, S.A. is focused on the design, manufacture and supply of fuel assemblies to Spanish and international power plants. Enusa core business is the front end of the nuclear cycle, which includes everything from the management and supply of enriched uranium to fuel manufacturing, as well as provision of engineering and fuel services to the nuclear power plants.

Present in the town of Juzbado, in the province of Salamanca, since 1985, the Enusa fuel assembly factory is one of the most innovative in Europe, as it incorporates latest generation technology that optimizes resources and protects the environment. This centre has a specialized, highly qualified team that covers the entire fuel production cycle: uranium supply and storage, and logistics of the components required for manufacturing, fuel production, product quality control, development of equipment for PWR, BWR and VVER product manufacturing and management of logistics and distribution to the plants throughout Europe.

The group of young participants could visit the main areas of Enusa fuel assembly factory:

- Ceramic area where it could be observed how the powder of uranium oxide and/or uranium oxide plus gadolinium is turned into high density sintered pellets.
- Mechanical area where ranges from the loading of the pellets in the rods to the manufacturing of the fuel assembly, including all the required inspections to ensure the final product quality.



Figure 4.- Technical Tour to ENUSA Fuel Assemblies Factory

4.2. Almaraz Nuclear Power Plant

Almaraz Nuclear Power Plant is located in the province of Cáceres, in the area known as Campo Arañuelo, cooled by water from the Arrocampo reservoir on the Tajo River.

There are two Westinghouse three-loop pressurized water reactors (PWR) operating on the site with an electric power of around 1000 MWe each one. Unit I was connected to the national grid in 1981 and the Unit II was connected two years later, in 1983.

As introduction, the visitors entered to the Information Centre, where there is a mockup of the plant and, basing on it, the improvements required from post-Fukushima nuclear stress tests were commented.

Inside the plant the group of young people could visit the turbine building, the electrical building, the control room, the technical support centre and one of the five emergency diesel generators. Subsequently, the visitors gained access to the controlled area, in particular, to the safeguard building, the auxiliary building and the fuel building where the Cherenkov effect could be seen glowing in the spent nuclear fuel pool.



Figure 5.- Technical Tour to Almaraz Nuclear Power Plant

4.3. Santa María de Garoña Nuclear Power Plant

The Santa María de Garoña Nuclear Power Plant is located in the meander formed by the Ebro River in the surroundings of the town that gave its name to the site, in the Tobalina valley in the province of Burgos.

In 1971, Santa María de Garoña was connected to the national electricity grid, achieving full power 27 days later, with 460 gross electric megawatts, which correspond to 1,381 thermal megawatts, the greatest amount installed in Europe at that date.



Figure 6.- Technical Tour to in Santa María de Garoña Nuclear Power Plant

The nuclear power plant has a Series 3 Boiling Water Reactor and Mark I type containment, which produces 466 MW of electric power and was supplied by General Electric Company.

Upon arrival the group was conducted to the Information Centre, receiving an explanation about the main characteristics of Series 3 BWR and an outline of how Fukushima accident happened, due to both plants are twin plants. Once it was understood how a BWR reactor works, the young people had the opportunity to visit the secondary containment, the pressure suppression pool torus and the spent fuel pool, as well as the emergency diesel generator building, the control room and the simulator.

4.4. ENSA Heavy Components Factory

ENSA is a worldwide leader in the supply of manufactured equipment and services for the civil nuclear industry.

ENSA factory is located in the north of Spain, in Maliaño (Cantabria), 9 km from Santander city. ENSA manufactures components in compliance with the most exigent standards, regulations and customer requirements. They are world leaders in supplying steam generators for nuclear power plants. They also supply reactor vessels, reactor vessel cover heads, reactor vessel internals, reactor vessel supports, casks for fuel storage and/or transportation, racks for fuel, nozzles for fuel and heat exchangers.



Figure 7.- Technical Tour to ENSA Heavy Components Factory

Tour participants visited the Advanced Technology Centre (CTA), where the materials and process performed during the manufacturing and test of the heavy components are developed, proved and qualified. The centre comprises four working units: metrology and materials testing laboratories, welding development, robotic applications and defectology. Finally they traversed the heavy nuclear components factory, being able to see casks for fuel storage and shipping up close, reactor vessel cover heads and to compare the steam generator from conventional PWR reactors with ones from AP1000 reactors.

5. Conclusions

The unanimous opinion of the participants was that taking part in technical tours is a worthwhile experience which has exceeded their expectations. Taking into account the interest awakened in the young participants, it can be concluded that visiting technical facilities is an overwhelming teaching practice which provides an excellent opportunity to experience at first hand the whole process of electricity production in nuclear power reactors.

All the performed technical tours were a complete success thanks to a generous care and know-how of the workers in charge of leading the technical tours.

Spanish Young Generation in Nuclear is extremely grateful to the Spanish Nuclear Society for the support for all the activities accomplished.

6. References

- Jóvenes Nucleares www.jovenesnucleares.org
- Enusa Industrias Avanzadas S.A. <http://www.enusa.es/enq/index.html>
- Centrales Nucleares Almaraz – Trillo <http://www.cnat.es/>
- Central Nuclear Santa María de Garoña – NUCLENOR <http://www.nuclenor.org/>
- ENSA <http://www.ensa.es/>